DESIGN AND CONSTRUCTION OF A RESEARCH FACILITY TO COMPARE MECHANICAL AND GRAVITY SETTLING FOR DAIRY MANURE SEPARATION

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INTRODUCTION

As environmental requirements become increasingly stringent, dairy producers are raising many questions about the proper storage and utilization of animal wastes as generated in today's total confinement operations. As of January 1, 1992, all new dairies must meet "no-discharge" guidelines as outlined by the Mississippi Department of Environmental Quality (Hardy 1996). Existing DEQ permits, which allow a legal discharge, will be systematically converted to the "no-discharge" criteria. These changes will undoubtedly ignite a series of questions about waste management alternatives that achieve "no-discharge" with minimal cost.

Since many dairy producers already utilize a lagoon waste treatment system, the land application of lagoon wastewater via irrigation has become increasingly popular. A limitation of using irrigation for land application of dairy lagoon wastewater is the need for specialized equipment to handle the bulk solids (bedding, feed, etc.). This has prompted the development of various manure solid separators which remove most of the bulk solids from the waste-stream. This can be beneficial, particularly if lagoon wastewater is applied with conventional clean-water irrigation equipment. Manure solid separators have been in use for many years, but the advent of more rigorous environmental regulations has increased their popularity. When these systems are employed, the bulk solids are removed by mechanical methods (screens, centrifuges, extruders, etc.). The remaining waste-stream continues to the lagoon for subsequent treatment.

While the removal of manure solids can improve the ability to land apply wastewater using irrigation methods, the dairy producer must now handle two separate waste-streams, liquid and solid. This situation has agronomic, economic, and environmental implications to the dairy producer. This was the catalyst to establish a manure solids separation research facility at the Bearden Dairy Research Center in Sessums, Mississippi.

THE BEARDEN DAIRY RESEARCH CENTER (DRC)

Facilities and Land Resources

The DRC is a true research dairy facility containing two double-4 herringbone milking parlors as shown in Figure 1. Each parlor is equipped with separate milk holding tanks and all associated milking hardware. A single observation tower between the two parlors allows cows from each respective group to be observed without disturbing the animals. Each parlor is equipped with indexing stalls and electronic cow identification. The dairy herd has approximately 130 Holstein and 40 Jersey cows. Replacement heifers (approx. 400) for all MSU dairy facilities are maintained at the DRC. The DRC is situated on 1,100 acres with the following divisions: 410 acres crop and hay, 425 acres pasture, 125 acres woodland, and 140 acres other (buildings, roads, drainage, etc.).

The DRC is a total confinement operation and provides two separate free-stall units to facilitate the split design of the research dairy. The two free-stall buildings are 92 x 132 feet (see Figure 2) with 96 and 104 cow capacities, respectively. The free-stall barns feature an insulated roof and a center ridge vent to facilitate cooling. In addition, fans and sprinklers are mounted in the free-stall barns to maintain cow comfort during high heat days.

Waste Handling System

The DRC features gutter flush-style waste removal for holding pens (shown in Figure 3) and free-stalls (shown in Figure 4). Flush water for the holding pen is provided by a 6,000 gallon elevated flush tank shown in Figure 5. The flush tank is connected with 12-inch diameter pipe to manually operated pop-up flush valves. Free-stall alleys are flushed with manually operated rising-curtain style gates. The water capacity for each alley is 1,200 or 1,500 gallons depending on the location along the building (see Figure 6).

Water from flushing is collected in a concrete trough at the rear of the free-stall facilities which subsequently connects to an 18-inch steel pipeline that discharges to the primary lagoon. The DRC features a three-stage lagoon system. The primary (1^{st} stage) was designed to provide anaerobic digestion with stages two and three designed to provide aerobic treatment. A recirculation pump is installed in the third lagoon with the ability to refill all flush tanks in the system (the flush tanks can also be refilled with clean water).

Bedding

Sand is the bedding material of choice at the DRC. Since sand is inorganic and does not serve as a substrate for microbial growth, it an ideal bedding material from the dairyman's perspective. Figure 7 shows free-stalls bedded with sand at the DRC. Unfortunately, from an engineering perspective, the sand poses a serious problem to the proper long-term function of the treatment lagoon. As can be seen in Figure 8, the sand used as free-stall bedding (about 7 cubic yards per week) is literally flushed to the treatment lagoon (note the large build-up of sand at the end of the discharge pipe). At present, the primary lagoon is almost completely full of sand and will require a drag-line or excavator for proper restoration. This will be expensive and would not be necessary if proper sand removal technologies were in place at the DRC.

DESIGN OBJECTIVES

The primary design goal was to develop a facility that removed manure bulk solids and sand. Features that would allow researchers to quantitatively measure the solids removal efficiencies of both mechanical and gravitational separation technologies were sought.

Manure Solids

A mechanical separator was chosen to remove bulk manure solids. This type of system is already being employed in some Mississippi dairies and represents a technology that is economically feasible for many Mississippi dairy producers.

Sand Removal

There are basically two methods of solving the sand build-up problem at the DRC. The first logical choice would be to stop using sand as a bedding material. The sand bedding could be replaced with organic bedding such as wood chips, straw, etc. Unfortunately, this solution may not be the best solution with regard to animal health, since organic bedding can promote microbial activity. This, in turn, may lead to higher somatic cell counts (an indicator of udder health and mastitis), although other factors such as bedding management also affect somatic cell counts. The second alternative is to strip (or remove) the sand from the waste-stream. This prevents sand from reaching the treatment lagoon, while still providing the dairyman with an option to use an inorganic bedding product like sand. This option becomes even more attractive, from a research standpoint, when one considers that approximately 75 percent of free-stall equipped dairies in Mississippi use sand for bedding (Moore 1996). With this in mind, the goal was to design and construct a research facility that would allow mechanical and gravitational solids removal technologies to be quantitatively compared. This was achieved by incorporating three basic components:

1. a mechanical manure solids separator;
2. a settling basin for sand removal; and
3. a storage pad that would allow manure solids and waste sand to be stored.

Design Limitations

Land surveying at the DRC site revealed only 3-feet of fall from the existing wastewater discharge outlet and the water surface of the primary lagoon. It was decided that the facility would be designed such that all liquids (whether via rainfall or incoming wastewater) would drain (via gravity) to the primary lagoon. This limited the operational depth of the settling basin to approximately 2-feet. While this was not ideal, it is sufficient to remove sand from the waste-stream.

APPARATUS

Design objectives were achieved by designing a solids separation treatment train which has mechanical separation and gravitational settling technologies arranged in a serial treatment train. In the treatment train, wastewater from the dairy flows first through the mechanical separator and then through the settling basin before finally discharging to the lagoon. This provides both mechanical and gravitational separation to the wastewater stream. In addition, the system was designed to allow wastewater to bypass the mechanical separator and flow directly into the settling basin. This feature will provide researchers with the opportunity to quantitatively compare gravitational and mechanical separation.

The manure separation research facility is composed of three basic components: the concrete storage pad, the foundation and support wall for the mechanical separator, and the gravitational settling basin (GSB). Each component will be described in more depth in the following sections.

Concrete Storage Pad

The manure solids separation facility, shown in Figures 9 and 10, is basically a 48 x 75 feet concrete bunker. The facility is approximately 6-feet below the ground surface due to the location of the existing flush drain line. This increased costs in the form of additional earthwork. It should be noted that this type of excavation may not be necessary for other dairies utilizing flush systems. Walls are 8-inches thick with steel reinforcement on 16-inch centers. The slope of the storage pad floor (1:10, rise:run) is such that all types of equipment (skid-steer loader or tractor with front-end loader) can easily move in and out of the facility, even in wet weather conditions. The size of the storage pad was dictated by the desire to be able to store manure solids and waste sand for about 90 days. This allows the manure solids and waste sand to be stored during the wet winter months when it is both environmentally and agronomically inefficient to land apply waste. The cost of the concrete storage pad (including the mechanical separator foundation) was approximately $17,000 including labor and materials.

Mechanical Separator

The first component in the solids separation treatment train is the mechanical separator (Agpro, Model 24L) as shown in Figure 11. This type of separator uses an inclined stainless steel screen to filter bulk solids out of the waste-stream. As bulk solids accumulate on the inclined screen, a conveyor belt scraps them upward across the screen to be discharged onto the storage pad as shown in Figure 12. The separator requires 120-volt AC power to drive the conveyor belt. The unit is approximately 11-feet tall and 14-feet long.

A 12-inch PVC pipe was installed to connect the existing drain line to the mechanical separator. Through the use of two 12-inch globe valves, the waste-stream can be diverted directly to the gravitational settling basin. This provides a failsafe mode when mechanical problems are encountered with the separator. In addition, diverting the waste-stream directly to the gravitational settling basin will allow researchers to determine the trapping efficiency in a "settling basin only" operational mode.

The separator includes a vertical sluice-gate operated by a mechanically linked float to control the amount of wastewater allowed to enter. A mercury float-switch engages the conveyer when sufficient wastewater has entered the separator. Processed wastewater exits the separator through a 12-inch PVC pipe and is then routed to the gravitational settling basin.

Gravitational Settling Basin

The design of the gravitational settling basin (GSB) was dictated (and somewhat compromised) by the lack of elevation (fall) from the existing wastewater discharge outlet and the primary lagoon (approximately 3-feet). While the 2-feet of active settling depth in the final design is sufficient for research purposes, it requires frequent clean out (max. three days). The design criteria used in designing GSB was based on many factors including: frequency of flushing, quantity of flush, sand utilized, and detention time.

The slope of the ramp going down into the GSB is the same as that of the storage pad (1:10, rise:run). The width of GSB was set at 12-feet so that two passes would provide needed overlap (the bucket is 8-feet wide, thus two passes yields a 4-foot overlap). This enhances efficiency during clean out.

The GSB volume, while dictated largely by the small depth, was designed to hold about 4,000 gallons at 70 percent capacity. Calculations on the flush volume revealed that each free-stall barn and the holding pen uses about 4,000 gallons of flush water per cycle. Therefore, one main building (either free-stall or the holding pen) can be flushed and be wholly contained in the basin. The other design criteria sought was that of sand storage. The GSB will hold approximately 20 cubic yards of sand (one dump truck load) at 70 percent capacity.

The GSB features two separate discharges which are subsequently routed to the primary lagoon. The primary discharge is offset from the main sidewalls of the GSB to allow for easy clean out. A removable steel gate with a series of orifices (approx. 3-inches in diameter) cut into the upper six inches serves as the baffle to prevent sand and large manure solids from exiting the GSB. As the depth of wastewater in the GSB increases above 18 inches, wastewater flows through the orifices allowing a controlled discharge to the lagoon (approx. 0.6 cfs maximum). The wastewater then drains via gravity through an 8-inch PVC pipe to the primary lagoon. The second drain is placed at the far end of the separator and serves as an emergency overflow. It is routed to the existing 18-inch drain line. This prevents wastewater from back flooding the storage pad.

The flow path (the distance from the effluent inflow to the effluent outflow in the settling basin) is 23-feet minimum. The purpose of moving the discharge as far from the outlet as possible is to reduce the velocity of inflow, thus allowing the sand and some manure solids to settle.

OPERATIONAL OBSERVATIONS

The facility went online in late October 1995 and much has been learned regarding the usage of a mechanical separator and gravitational settling basin (GSB) to date. The unit was rendered inoperable within one month of going online due to foreign debris (whole brooms, cats, placentas, etc.) jamming the conveyer belt. The author determined that a sensor and control device needed to be implemented on the separator to automatically shut it down when this type problem was encountered. The mechanical separator was subsequently fitted with the first commercially released version of the sensor. The inclusion of the sensor and training sessions with DRC employees has substantially reduced the problems associated with the mechanical separator; however, the system still requires frequent inspections and maintenance.

Clean out of the GSB takes approximately 20 to 40 minutes and this is largely dependent on the operator of the skid-steer loader. Waste sand and settled manure solids are stored on the storage pad. To date the storage area has easily contained two months of manure solids and waste sand. These solids were then land applied using a standard manure spreader.

Thus far, the settling basin is doing an excellent job of removing the sand from the wastewater stream, provided it is cleaned out periodically (at least every three days). Figure 13 shows the solids removed from the GSB (predominantly sand) and the mechanical separator (predominantly manure solids). Preliminary data has shown a total solids content (dry basis) of 2.7 grams/liter in the influent, 0.5 grams/liter post separator, and 0.2 grams/liter post GSB, representing 81 and 93 percent solids reduction, respectively.

FUTURE WORK

The research team is presently implementing a sampling system to automate retrieval of wastewater samples for solids measurements. Measurement of volatile solids, total solids, and suspended solids will begin once the sampling apparatus is in place.

REFERENCES

Hardy, Mike. 1996. Environmental Scientist II, Mississippi Department of Environmental Quality Personal communication.

Moore, R.B. 1996. Associate dairy scientist, Animal & Dairy Science Department, Mississippi State University. Personal communication.

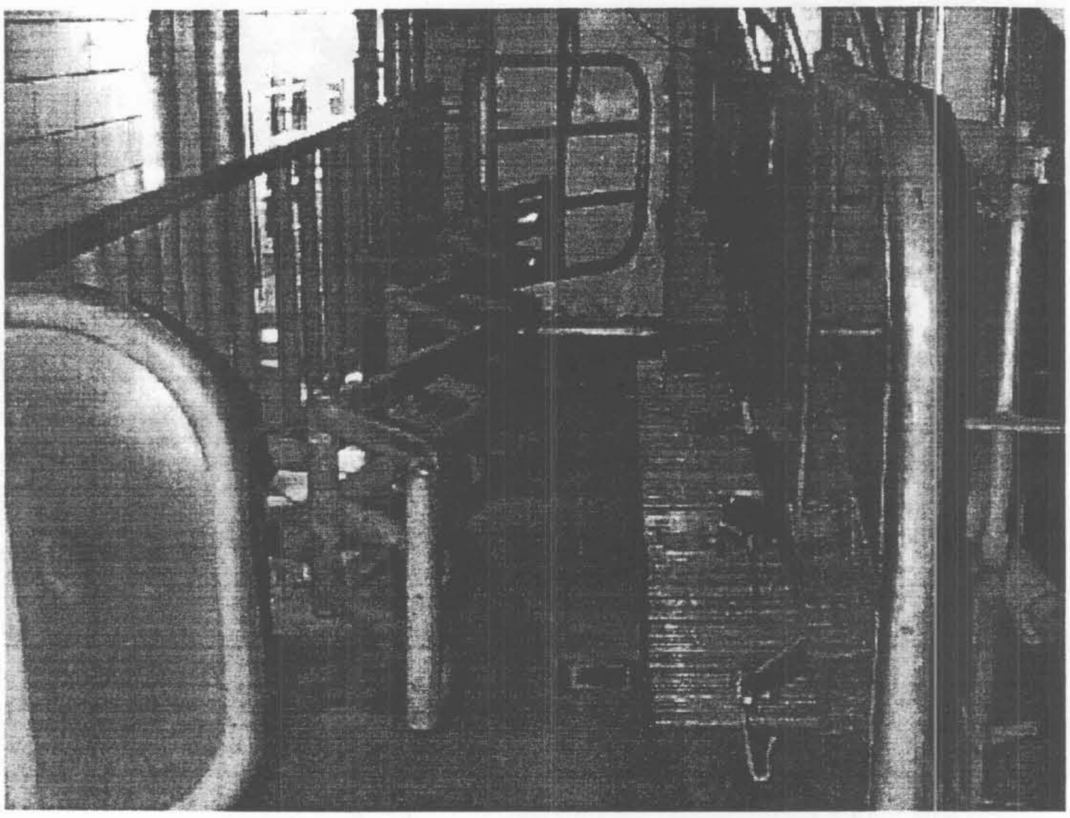
Figure 1. Double-four Herringbone milking parlor at the Bearden Dairy Research Center, Sessums, MS.

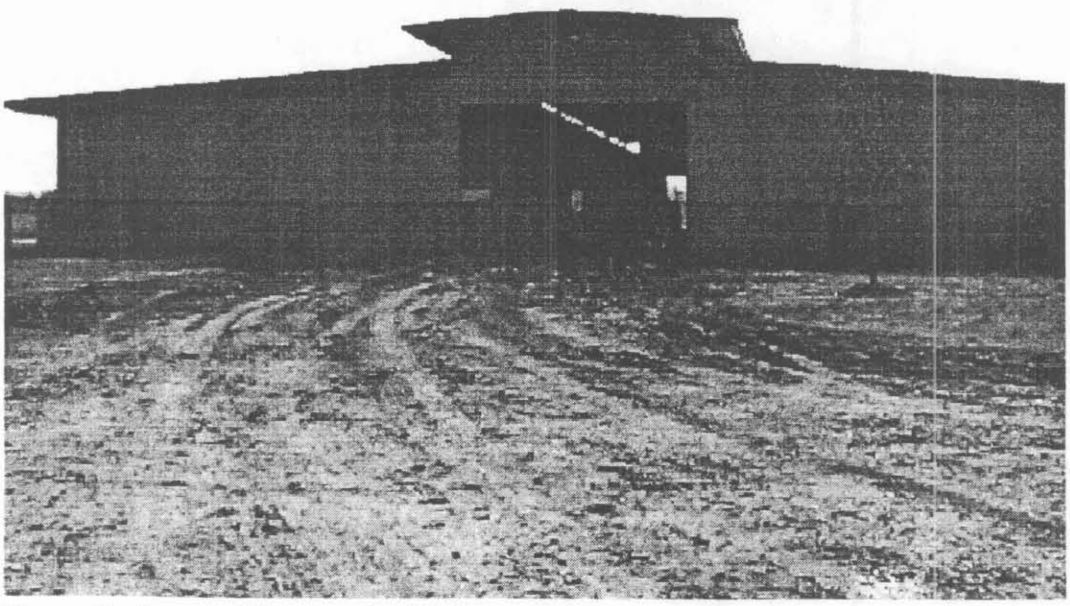
Figure 2. Free-stall barn at the DRC.

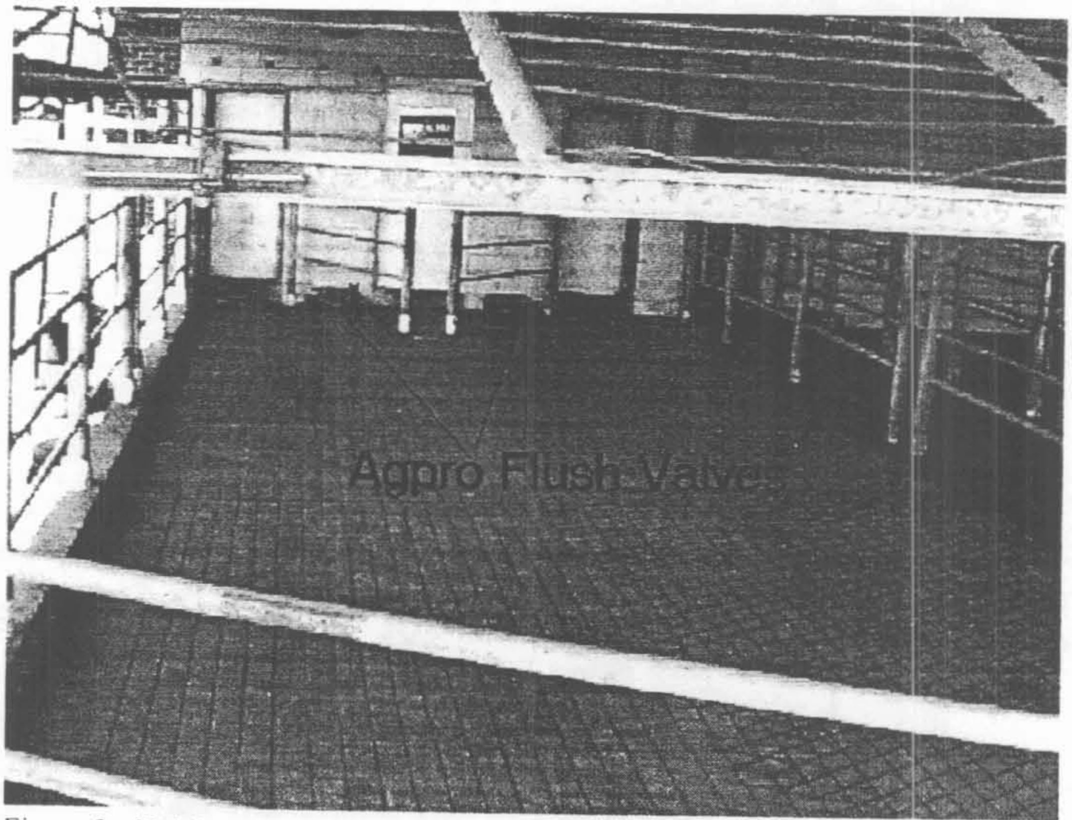

Figure 3. Holding pen showing location of Agpro pop-up flush valves.

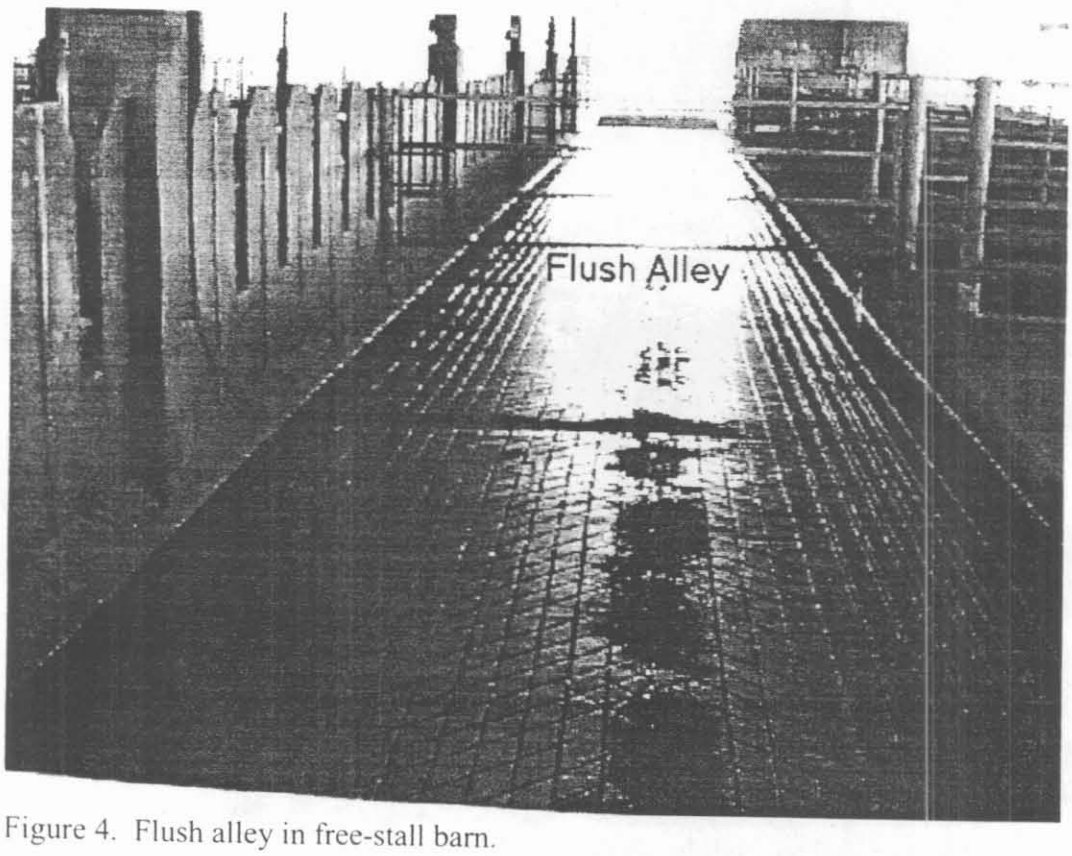

Figure 4. Flush alley in free-stall barn.

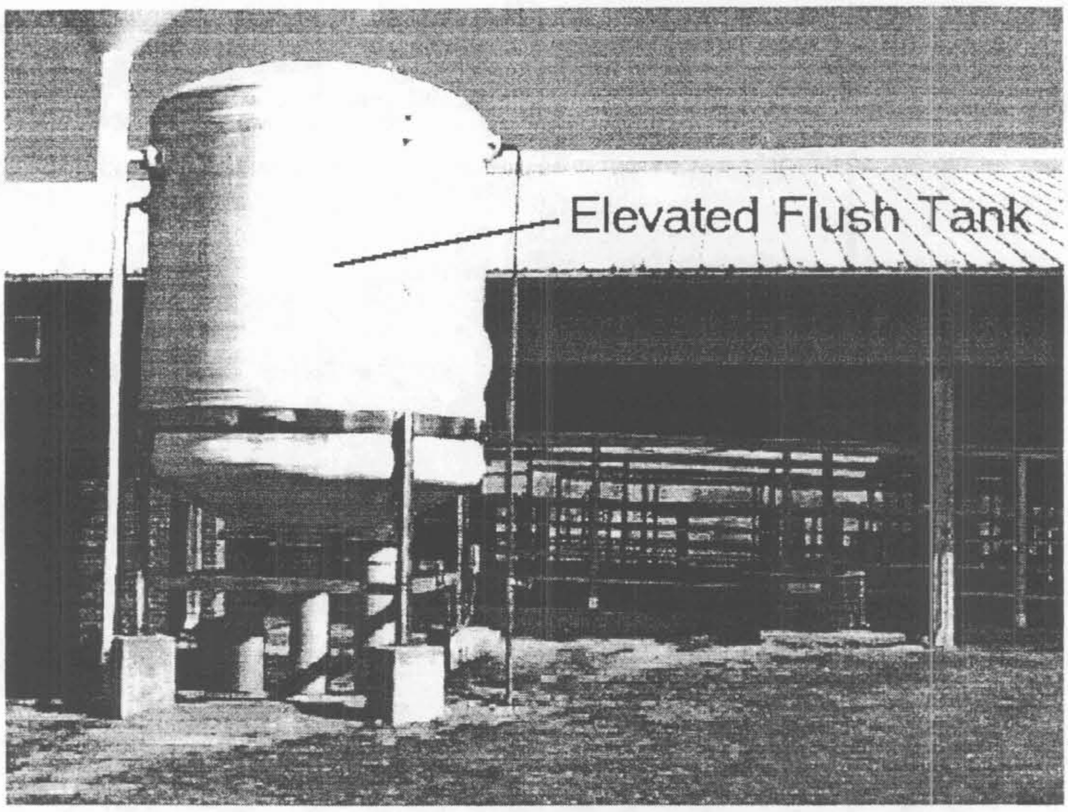

Figure 5. Flush tank servicing the two holding pens.

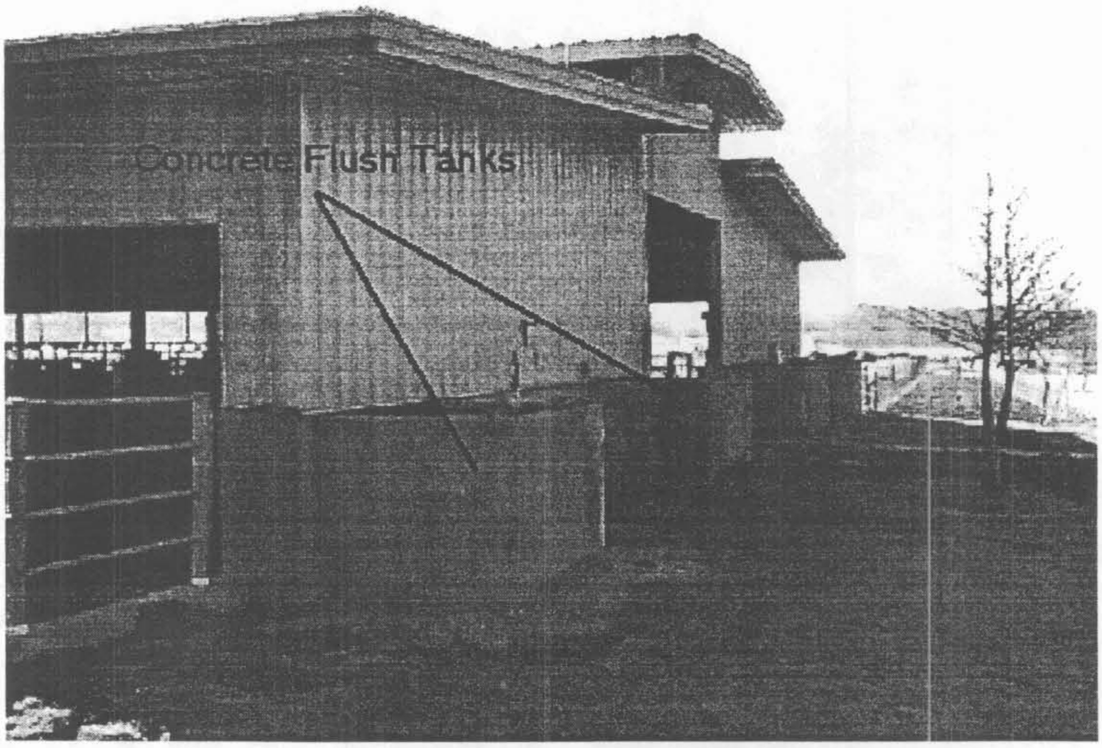

Figure 6. Free-stall flush tanks (1200 and 1500 gallons, respectively).

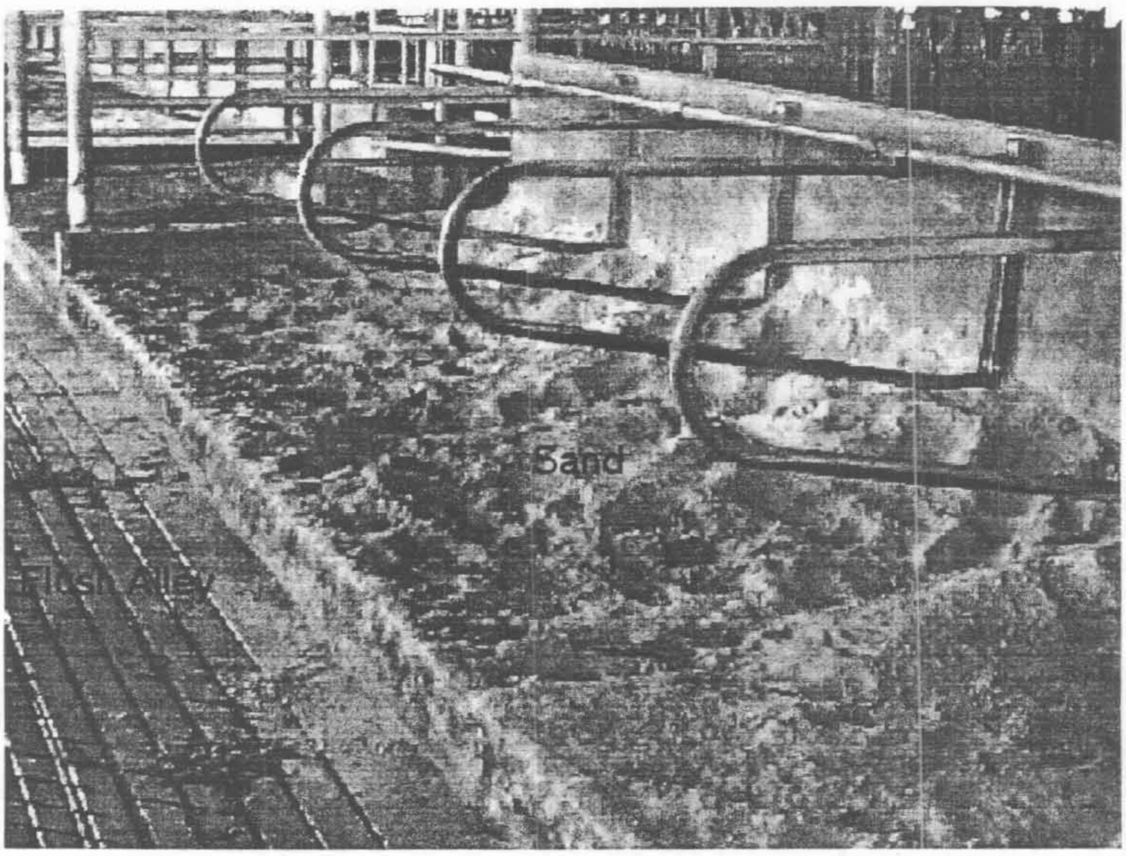

Figure 7. Free-stall padocks with sand bedding.

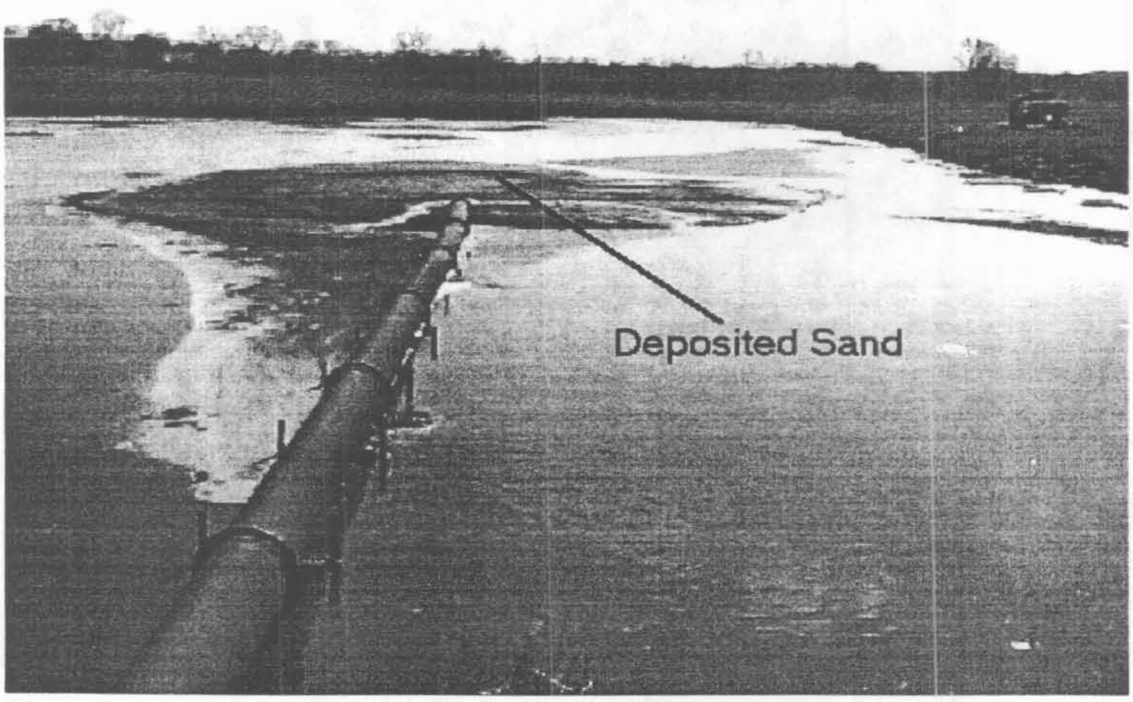

Figure 8. Primary DRC anerobic lagoon showing deposited sand.

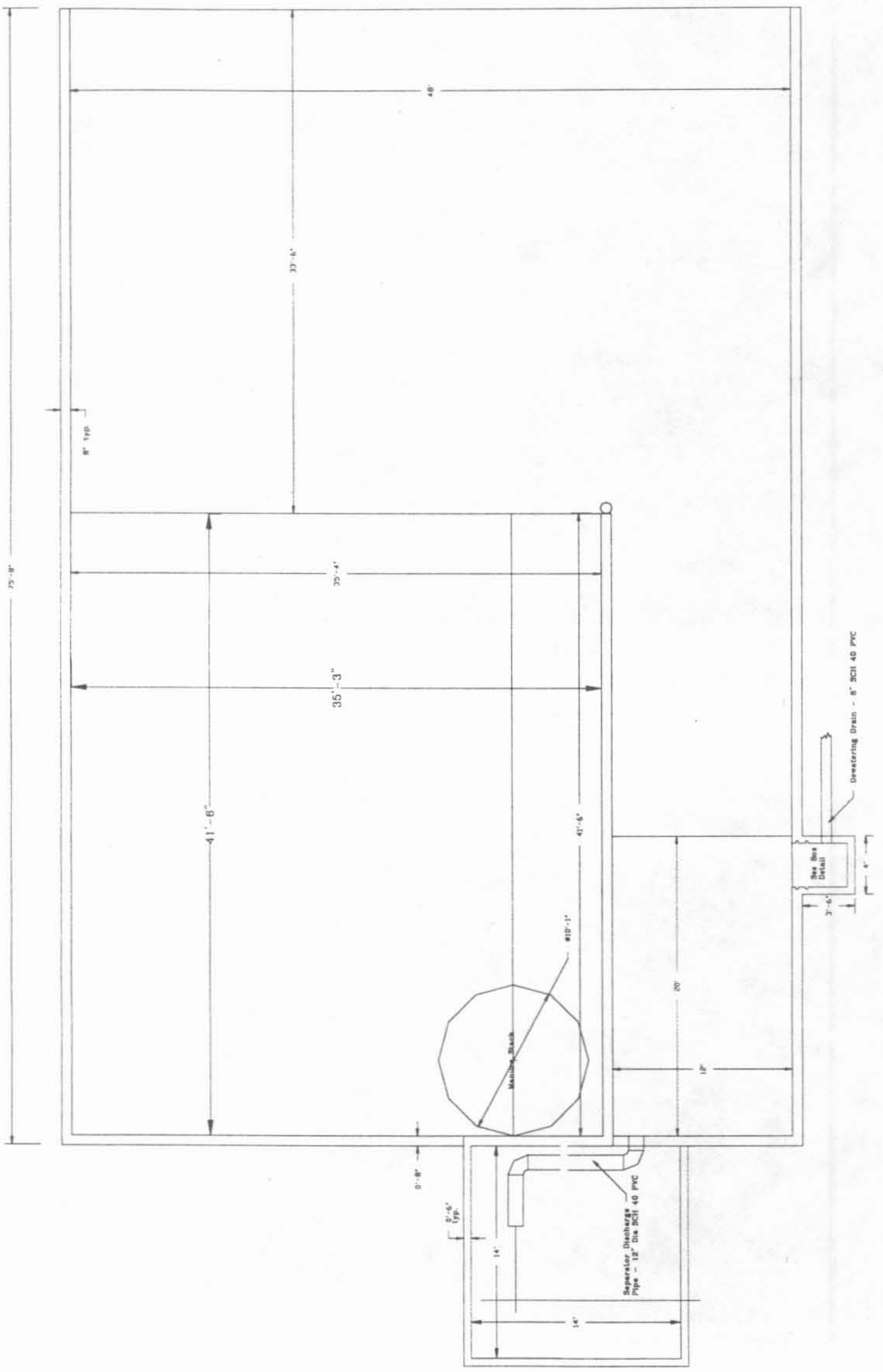

Figure 9. Plan view of manure separation facility.

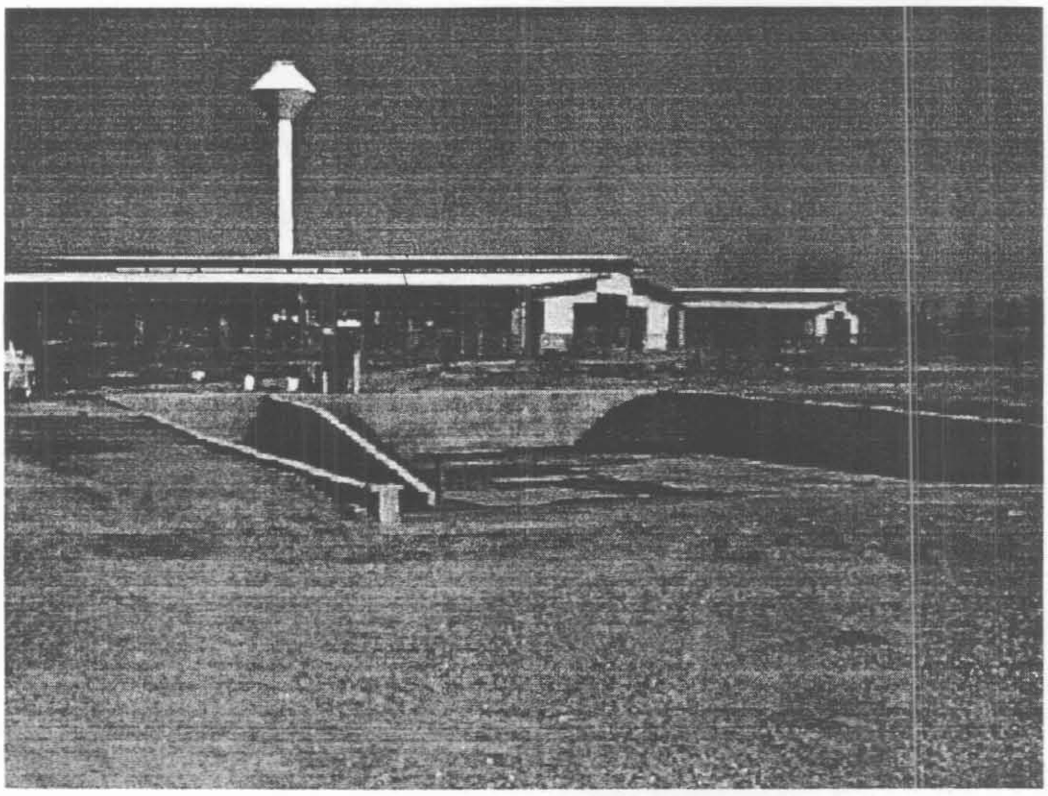

Figure 10. Overall view of separation facility located at the Bearden Dairy Research Center, Sessums, MS.

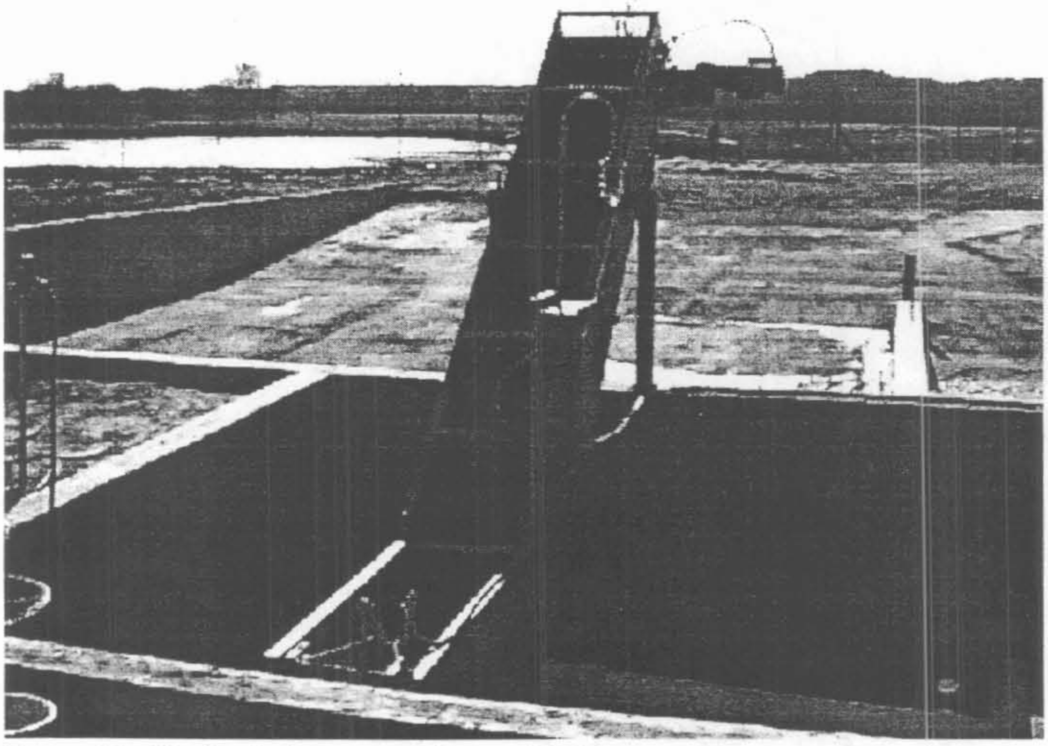

Figure 11. Mechanical separator (Agpro Model 24L).

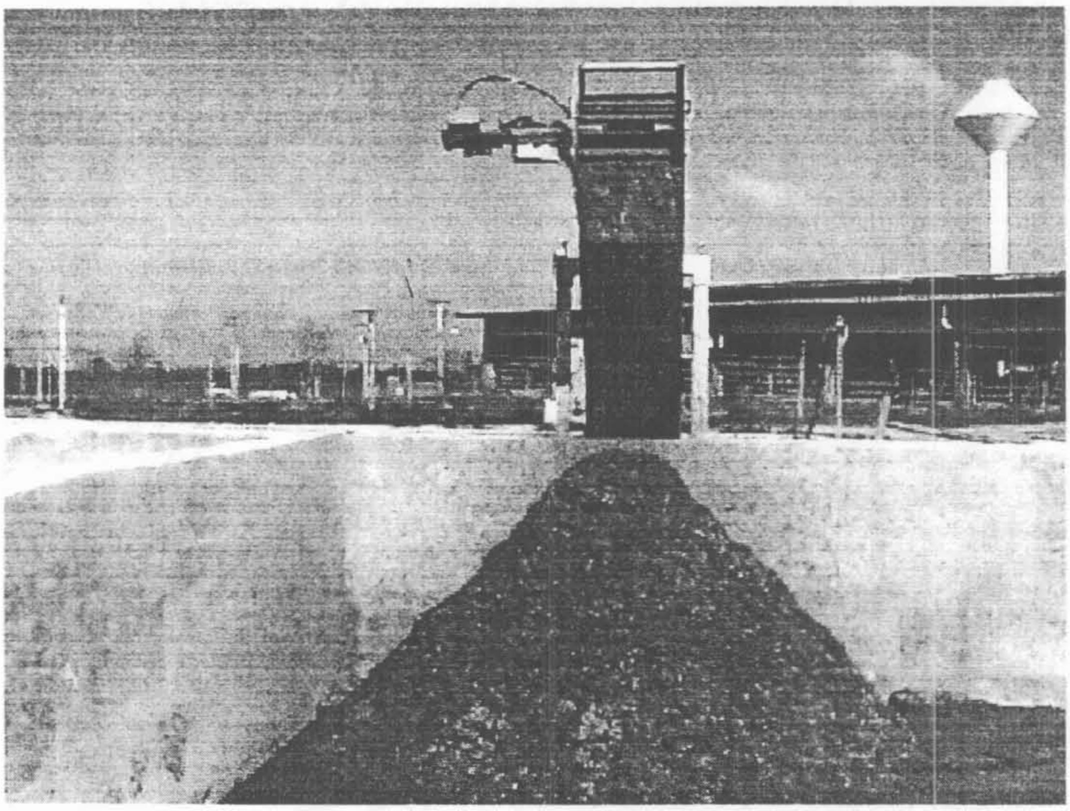

Figure 12. View of mechanical separator with manure solids discharged onto the storage pad.

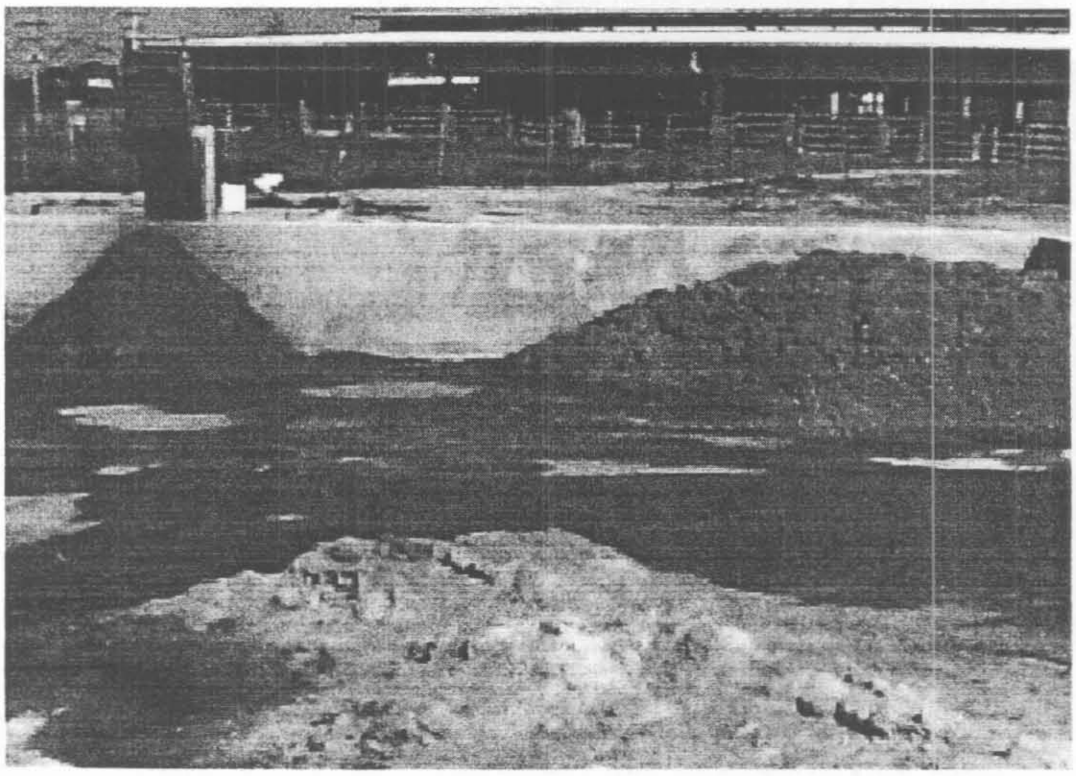

Figure 13. Storage pad with waste sand in the foreground and manure solids in the background.